Non-ideal MHD effects for magnetic flux tubes in the photosphere

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Magnetic flux tubes reaching from the solar convective zone into the chromosphere have to pass through the relatively cool photosphere. The photospheric plasma has a degree of ionization of less than 0.01 % and a temperature of about 4200 K. It thus forms a non-ideal region with non-vanishing resistivity enclosed between the highly ideal sub-photospheric and chromospheric plasma. It is shown that stationary MHD-equilibria of magnetic flux tubes which pass through this region require an inflow of photospheric material into the flux tube and a deviation from iso-rotation along the tube axis. This means that there is a difference in angular velocity of the plasma flow inside the tube below and above the non-ideal region. Both effects increase with decreasing cross section of the tube. Although for characteristic parameters of thick flux tubes the effect is negligible, the scaling law indicates its importance for small-scale structures. The relevance of the inflow of photospheric material for the expansion of flux tubes above the photosphere is discussed, as well as the implications of the deviation from iso-rotation for the commonly used assumption of flux tubes being frozen in the photospheric plasma.

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